office under some form of the merit system, (2) that is compensated at a rate sufficient to attract persons of high professional caliber, and (3) that is routinely notified of and empowered to investigate every death due to violent or to obscure causes.

The survey disclosed that the cost of maintaining such a service in metropolitan areas is not significantly greater than that of the average coroner's office and should probably be between 4 and 6 cents per capita per year. It was found that the inability or unwillingness of communities to provide for a competent medical agency for investigating deaths due to violent or obscure causes predisposes to: (a) Non-recognition of murder; (b) unjust accusation of innocent persons; (c) improper evaluation of medical evidence bearing on the circumstances in which fatal injuries were incurred; (d) failure to acquire medical evidence which would be useful in the apprehension of criminals; (e) failure to acquire medical evidence essential to the administration of civil justice; (f) ignorance of certain otherwise preventable hazards to public health, and (g) the impairment of the value of vital statistics.

It would appear to be incumbent on the physicians of California to scrutinize the manner in which medical science is being utilized to investigate deaths in the interests of justice and public health and to take such steps as may be necessary to bring this important professional activity to a plane comparable with that of other forms of medical practice.

Parenteral Fluid Therapy During Prolonged Surgery*

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EXPERIENCE at an Army hospital in the zone of the interior where many surgical procedures were long, and the problems of dehydration and blood loss therefore intensified, emphasized the importance not only of careful supervision of supportive parenteral fluid therapy by the anesthesiologist but of a readily available blood bank and the advisability of forehanded preparation of the patient for transfusions.

Since a potentially dangerous loss of fluid is to be expected in long operations, this discussion concerns the prevention of dehydration, the use of saline solutions and plasma as temporary blood substitutes, and massive transfusions of whole blood during protracted surgery.

LITERATURE

One of the greatest problems for the anesthesiologist during prolonged surgical procedures is the fairly accurate estimation of the progressive blood loss and the evaluation of its immediate significance. There is no single reliable test or clinical sign of impending shock, especially in anesthetic and post-anesthetic states. Our conception of the amount of blood lost in the course of a given operation may be obtained by reviewing the studies of Coller,[4] and Gatch,[5] and others.[6,7,8] In 1924 Gatch and Little[5] reported the first study of blood loss during some of the more common operations in general surgery in which accurate measurement of the losses were made. Everyone who has done such studies has been impressed that the blood loss at operation is often several times greater than that estimated by the surgeon. This is particularly true of the constant ooze of blood from large vascular fields during difficult dissections. Alexander Blain[3] in 1929, in commenting on his experience with 3,000 transfusions, urged the preoperative correction of anemia and the immediate replacement of blood lost during operation and condemned delaying blood transfusions until after shock had developed.

Concurrently with the blood loss determinations, Coller and his associates[4] made observations of changes in hematocrit, hemoglobin and plasma protein concentration before, during, and after operation. They found no correlation between the amount of blood lost and simultaneous changes in hematocrit, hemoglobin and concentration of plasma protein immediately before and after operation, and concluded that these determinations cannot be used to estimate the need for blood volume replacement during and after operation. Obviously, if one wishes to know precisely the amount of blood lost in any operation one must depend on direct measurement. Since this is not practical, one must rely primarily on a knowledge of average losses to provide a basis for the replacement of blood loss during operation. Coller[4] further emphasizes that all loss over 300 cc. in healthy adults should be replaced and that all blood loss in operations on aged, undernourished, seriously ill or bedfast patients should be replaced with equal quantities of blood.

In Table 1 is shown the blood loss during operation studied by Gatch and Little.[2] Table 2 shows the blood loss in operations of various kinds in

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626 cases compiled from the literature by Coller and his associates.[4] Table 3 presents the blood loss during operations reported by Coller.[4]

Coller believes that not enough emphasis has been placed on the relation of the amount of blood lost to the total blood volume. He further points out that since the blood volume varies with the weight of the patient, it makes a vital difference whether a given amount of blood is lost from a large adult or from a small child. In Table 4 are shown some figures illustrating the relationship of a 100 cc. blood loss to the blood volume in patients of differing weights. A simple method of calculating blood volume is to allow 35 cc. of blood for every pound, or 75 cc. for each kilogram, of body weight.

TABLE 1.—*Average Blood Loss During Operations Studies by Gatch and Little*[5]

Appendectomy, McBurney	7 cc.
Thyroidectomy	208 cc.
Radical breast	710 cc.
Laminectomy, fractured spine	672 cc.
Nephrectomy	816 cc.
Hysterectomy	232 cc.
Cholecystectomy	87 cc.

TABLE 2.—*Blood Loss in Operations of Various Kinds in 626 Cases Compiled from the Literature by Coller et al.*[4]

Operations	Number of Cases	Blood Loss: Maximum, Cc.	Minimum, Cc.	Average, Cc.
Brain	30	2,150	487	1,084
Postganglionic neurotomy (trigeminal)	4	650	86	337
Spinal cord	7	1,264	107	626
Thyroidectomy	29	1,118	16	237
Other neck operations	3	410	105	230
Mastectomies, radical	20	1,272	254	732
Mastectomies, simple	5	220	180	200
Thorax	113	2,895	35	575
Splenectomy	2	990	160	525
Intestinal above sigmoid	11	230	10	81
Appendectomy	14	62	4	13
Sigmoidal, rectal, and anus	21	1,220	8	377
Hernia	13	306	11	74
Miscellaneous abdominal	6	546	14	218
Pelvic	30	680	22	266
Prostatic resections, transurethral	220	1,254	4	280
Kidney	10	1,144	130	372
Orthopedic	31	1,564	40	441
Stomach	41	650	45	233
Biliary tract	16	400	51	100

In 1943 Frederick Allen[2] advanced some thought-provoking views regarding the use of large saline infusions intravenously as a temporary means of maintaining an adequate blood volume, compatible with life. He pointed out that in hemorrhage, just as in other forms of shock, there is an alteration of such a nature that large saline infusions are not quantitatively lost from the blood stream within 24 hours as they are in normal animals but on the contrary they may provide a volume of dilute blood sufficient to maintain life for hours or days. Thus plain physiological saline solution, when given in sufficiently large volume, may preserve life through an emergency or shock period until it is possible to obtain blood for transfusion.

POSSIBILITY OF EXCESS OF SODIUM CHLORIDE

With the administration of sodium chloride, there is the constant potential danger of overestimating the bodily need for sodium. Such an excess of sodium chloride often results in fluid retention and in a urine volume that is extremely small in proportion to the fluid intake. It must be remembered that pulmonary edema is an immediate danger whenever parenteral fluids are given in excessive amounts or at an excessive speed. Allen[2] admits this danger, but believes that when a patient is suffering from the dangerous anoxemia associated with an inadequate blood volume following hemorrhage, life-saving intravenous administration of huge volumes of normal saline solution should be rapidly given until whole blood becomes available. Pulmonary edema may be combatted if and when it arises, but the inadequate blood volume with

TABLE 4.—*Relationship of Blood Loss to Total Blood Volume*[4]

Weight (lb.)	Total Blood Volume (cc.)	100 cc. Loss Expressed as a Percentage of the Whole
10	450	22.0
20	890	11.0
40	1,600	6.2
80	2,825	3.6
140	5,000	2.0
200	7,000	1.4

TABLE 3.—*Blood Loss During Operations Studied by Coller et al.*[4]

Operations	Number of Cases	Blood Loss: Maximum, Cc.	Minimum, Cc.	Average, Cc.	Total Volume %
Mastectomy, radical	4	1,091	529	821	17.7
Thyroidectomy	8	725	99	379	11.7
Biliary tract, secondary and plastic	8	1,455	158	594	14.6
Rectal, combined abdomino-perineal	12	686	183	410	9.5
Stomach, complicated	3	804	321	599	13.6
Chondroma, presacral	1	......	......	1,257	39.6
Thyroidectomy, intrathoracic	1	......	......	1,397	20.6
Sarcoma of shoulder and hemiscapulectomy	1	......	......	857	22.9

its resultant anoxemia must be first improved.

Adams and his coworkers,[1] who studied the problem of citrate intoxication in massive transfusions of whole blood, concluded that it would be practically impossible to duplicate clinically in man the rapid rate of administration of citrated whole blood or plasma necessary to result in citrate intoxication, since this would necessitate the giving of over 4,000 cc. of blood to a 70 kg. man during a five-minute period. Thus they demonstrated that a large margin of safety is present in massive transfusion of citrated whole blood or plasma when the administration is at a maximum rate currently employed in man (1,000 cc. per hour). They found that calcium gluconate was very effective in preventing or alleviating citrate intoxication when very large doses of citrate had been administered during a short period of time.

PRESENT STUDY

The situation encountered at an Army hospital offered unusual opportunity for observations on the problem of blood loss and replacement during operations, in that a large percentage of the cases were those requiring the notoriously long reconstructive surgical procedures. Of 2,602 operations performed between August 1, 1944, and August 1, 1945, 710 lasted longer than two hours and 84 of these took over five hours.

As preface to a relation of experience with these cases, it is noteworthy that the patients for the most part were in excellent physical condition. Their average age was 27 years and they were in a good state of nutrition, as they had convalesced from the fatigue, exposure, malnutrition, shock, and acute infection commonly encountered in forward medical units. Hence it may be assumed that measures found advisable with these patients are even more applicable, in long surgical procedures, to civilian patients, whose condition generally cannot be expected to be as good as that experienced in military personnel.

In reviewing experience in protracted surgery cases in the Army hospital, it should be pointed out that water is available for kidney secretion only after the skin, lungs and intestinal tract have taken up their prior rights. In prolonged operative procedures, in addition to the normal insensible loss of water from the skin and lungs, a surgical patient who is draped in the usual manner with sheets and towels and is under the rays of a battery of operating lights suffers an enormous fluid and salt loss during a five to ten-hour operation. In an Army hospital, this loss was particularly marked during the summer months when the temperature in the operating rooms, none of which were air-conditioned, often ranged between 90 and 100°F.

Loss of water by these avenues during a long procedure becomes all the more important because there is usually a deficient fluid ingestion throughout the immediate preoperative and operative period. This deficiency was anticipated and its effect lessened to some extent by forcing fluids whenever possible during the 24 hours preceding the immediate preoperative period, although the common preoperative order, "nothing by mouth after midnight," before general anesthesia was followed to safeguard against the aspiration of vomitus during the induction period.

During operative procedures, salt and dextrose solutions were found primarily useful for the correction of dehydration. They were not considered very effective as blood substitutes, as the elevation of blood volume and blood pressure through their use was looked upon as transient. Administration of salt and dextrose solutions by the intravenous route rather than by hypodermoclysis is preferred now that the problem of pyrogenic reactions has been successfully solved. Fluids administered intravenously are immediately available to the entire body, whereas the absorption of those given by clysis is slow and variable. The amount of these solutions given during an operation must depend upon the estimated loss of water and sodium chloride from the body. Usually in a five to ten hour operation during the summer months, it was found advisable to give three to five liters of solution intravenously. Of these, two to three liters consisted of 5 per cent dextrose in distilled water.

While no effort to satisfy caloric, protein and vitamin requirements was considered necessary during an operation, it was concluded that this should be included in the preoperative and postoperative care. Recently, amigen and nutramigen solutions have been used in increasing amounts both preoperatively and postoperatively in gastro-intestinal cases.

Although at first there was no blood bank at the Army hospital where these studies were carried out, it soon became apparent that such a facility was almost a necessity in order to insure immediate availability of blood in large amounts during operations on aneurysms, brain and spinal tumors, and extensive bone defects. One ten-hour operation, the transplantation of both ureters, required meticulous dissection of structures in a densely scarred and highly vascular field. During the procedure, three and a half liters of whole blood as well as two liters of liquid plasma, three liters of physiological saline solution, and two liters of 5 per cent dextrose in distilled water were given—a total of ten and a half liters of parenteral fluids in ten hours. Indicative of the extent of blood loss, the patient 48 hours later was found to have a value for hemoglobin of 48 per cent and 2,420,000 red blood cells, as compared with 109 per cent and 5,580,000 preoperatively. The plasma given to this patient was used as a blood substitute during the period when additional blood was being typed, crossmatched and drawn. This and similar cases demonstrated the need for a local blood bank, which was then established.

It was most reassuring to have the patient crossmatched with four to six bottles of bank blood before attacking an arteriovenous aneurysm of the sub-clavian artery and innominate vein. When such adequate precautionary preoperative crossmatching with bank blood was done, no additional emergency crossmatching was needed during the operative procedure.

The Rh determination was done on all patients receiving transfusions, and only Rh negative blood was given to Rh negative recipients. This was deemed advisable to prevent possible transfusion reactions due to anti-Rh agglutinations developing in patients receiving multiple transfusions during repeated reconstructive operations.

RATE OF ADMINISTRATION OF WHOLE BLOOD

The rate of administration of the whole blood depended upon the estimated amount and rate of blood loss by the patient and on the response of the blood pressure and pulse to that loss. Falling of blood pressure and rising pulse rate were considered an indication for an increase in the speed of administration of blood. Sometimes circulatory failure led to a complete collapse of the veins, and gravity alone was insufficient to cause a free flow of fluid. Then it might be necessary to force the blood in rapidly under pressure, either by (1) the use of a luer syringe attached to the three-way stopcock of the intravenous apparatus, or (2) by rolling the tubing toward the intravenous needle, or (3) by using a blood pressure bulb placed on the blood flask air inlet tube.

Experience in the Army hospital re-emphasized the advisability of carefully placing one and preferably two large gauge needles or cannulae into appropriate veins in the forearm or ankle before an operation is commenced. These may be kept patent by allowing a very slow drip of solution to flow through them or by leaving a stylet in place until the needle is to be used. Not infreqently, veins in the arms or the site of operation are poor and the ankle veins are the only one available. If these are small and do not distend following dependency and the proper application of hot towels, a "cutdown" and placement of cannulae should be done before beginning such surgical procedures as craniotomy, aneursysmorrhaphy, laminectomy, etc. This preoperative delay to permit the introduction of a large gauge needle pays tremendous dividends when rapid lifesaving administration of blood or plasma becomes imperative.

CONCLUSION

In conclusion it should be reiterated that supportive parenteral fluid therapy is a constant responsibility of the anesthesiologist and, further, that salt and dextrose solutions are primarily useful for the prevention of dehydration. Saline solutions and plasma are useful as temporary blood substitutes, but the most satisfactory method of maintaining the good condition of a patient during an operation in which much blood is lost requires the continuous replacement of whole blood.

Blood banks are a necessity in the modern hospital where repair of arteriovenous aneurysm, pneumonectomy, extirpation of brain tumor, or ligation of a patent ductus arteriosus is no longer considered unusual. Without a blood bank there is a tendency not to administer transfusions when indicated, or, when they are given, to use inadequate amounts of blood.

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